CONTENTS

SECTION I: CHAPTER 1
PERSONAL SAMPLING FOR AIR CONTAMINANTS

SECTION I: CHAPTER 1

PERSONAL SAMPLING FOR AIR CONTAMINANT

A. INTRODUCTION - SCREENING

The evaluation of potential employee overexposure by observing and taking screening samples before conducting partial or full-shift air sampling can facilitate the monitoring process.

Screening with portable monitors, Gravimetric sampling, or detector tubes can be used to evaluate the following:

- exposures to substances with exceptionally high permissible exposure limits (PELs) in relatively dust-free atmospheres, e.g., ferric oxide and aluminum oxide;
- intermittent processes with substances without short-term exposure limits (STELs);
- engineering controls, work practices, or isolation of process; and
- the need for SE/IH protection.

Take a **sufficient** number of samples to obtain a representative estimate of exposure. Contaminant concentrations vary seasonally, with weather, with production levels, and in a single location or job class.

The number of samples taken depends on the error of measurement and differences in results. Consult the *NIOSH Occupational Exposure Sampling Strategy* Manual for further information.

If the employer has conducted air sampling and monitoring in the past, review the records.

Bulk samples are often required to assist the laboratory in the proper analysis of field samples. (See Section I, Chapter 4, Sample Shipping and Handling.) Some contaminants in these categories are:

- silica,
- portland cement,
- asbestos,
- mineral oil and oil mist,
- chlorodiphenyl,
- hydrogenated terphenyls,
- chlorinated camphene,
- fugitive grain dust, and

- explosibility testing.

Bulk samples can also be taken and analyzed to support any Hazard Communication inspections (i.e., Material Safety Data Sheet determinations).

B. GENERAL SAMPLING PROCEDURES

Screen the sampling area with detector tubes, if appropriate. Determine the appropriate sampling technique (see Section on OSHA Computerized Information System [OCIS] Chemical Sampling Information - Chemical Information Manual). Prepare and calibrate the equipment and prepare the filter media.

Select the employee to be sampled and discuss the purpose of the sampling. Inform the employee when and where the equipment will be removed. Stress the importance of not removing or tampering with the sampling equipment. Turn off or remove sampling pumps before an employee leaves a potentially contaminated area (such as when he/she goes to lunch or on a break).

Instruct the employee to notify the supervisor or the IH if the sampler requires temporary removal.

Place the sampling equipment on the employee so that it does not interfere with work performance.

Attach the collection device (filter cassette, charcoal tube, etc.) to the shirt collar or as close as practical to the nose and mouth of the employee, i.e., in a hemisphere forward of the shoulders with a radius of approximately 6 to 9 inches. (Generally referred to as the breathing zone)

The inlet should always be in a downward vertical position to avoid gross contamination. Position the excess tubing so that it does not interfere with the work of the employee.

Turn on the pump and record the starting time.

Observe the pump operation for a short time after starting to make sure it is operating correctly.

Record the information required by the Air Sampling Data Form (OSHA 91(S)).

Check pump at least every two hours for general operation (if there is a failure, i.e., “off” or fault light has come on; **change pump and sample**) and flowrate. Record pertinent information as applicable. Ensure that the sampler is still assembled properly and that the hose has not become pinched or detached from the cassette or pump. More frequent checks may be necessary with heavy filter loading (observe for symmetrical deposition, fingerprints, large particles, etc.).

Periodically monitor the employee throughout the workday to ensure that sample integrity is maintained and cyclical activities and work practices are identified.

Take photographs (as appropriate) and detailed notes concerning visible airborne contaminants, work practices, potential interferences, movements, and other conditions to assist in determining appropriate engineering controls.

Prepare blank(s) during the sample period for each type of sample collected. (See Section I, chapter 4, Sample Shipping and handling.) One blank will suffice for up to 20 samples for any given analysis except asbestos, which requires a minimum of two field blanks. These blanks may include opened but unused charcoal tubes.

Before removing the pump at the end of the sample period, if there is a pump rotameter, check the flow rate to ensure that the rotameter ball is still at the calibrated mark. If the ball is no longer at the mark, record the pump rotameter reading.

Check the flow using a calibrated precision rotameter.

Turn off the pump and record the ending time.

Remove the collection device from the pump and seal it with an Cal/OSHA 1-HS form as soon as possible. The seal should be attached across sample inlet and outlet so that tampering is not possible. (See Figures I:1-1a and I:1-1b.)

Prepare the samples for mailing to the laboratory for analysis. (See Section I, Chapter 4.)

Recalibrate pumps after each day of sampling (before charging).
For unusual sampling conditions such as wide temperature and pressure differences from calibration conditions, call the Regional Sr. Industrial Hygienist or District Manager for advice.

Figure I:1-1a. *Improperly* sealed cassette allows access to inlet and outlet after sample has been taken.

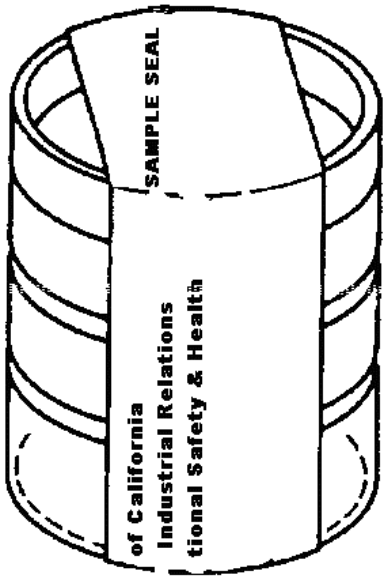

Figure I:1-1b. Properly sealed cassette with CAL/OSHA 1-HS form covering inlet and outlet ports provides security.

C. SAMPLING TECHNIQUES

DETECTOR TUBES

Each pump should be leak-tested before use.

Calibrate the detector tube pump for proper volume **at least quarterly** or after 100 tubes. (See Appendix I:1-1.)

TOTAL DUST AND METAL FUME

Collect total dust on a preweighed, low-ash polyvinyl chloride filter at a flow rate of about 2 liters per minute (L/min), depending on the rate required to prevent overloading.

Collect metal fumes on a 0.8-micron mixed cellulose ester filter at a flow rate of approximately 1.5 L/min, not to exceed 2.0 L/min. When the gravimetric weight needs to be determined for welding fumes, collect these fumes on a low-ash polyvinyl chloride filter.

Take care to avoid overloading the filter, as evidenced by any loose particulate.

Calibrate personal sampling pumps before and after each day of sampling, using a bubble meter method (electronic or mechanical) or the precision rotameter method (that has been calibrated against a reference standard positive displacement meter, i.e. bubble meter), as described in Section E.

RESPIRABLE DUST

Collect respirable dust using a clean cyclone equipped with a preweighed low-ash polyvinyl chloride filter at a flow rate of 1.7 $\pm$ 0.2 L/min. See Figure I:1-2.

Collect silica only as a respirable dust. A bulk sample should be submitted to the laboratory.

All filters used shall be preweighed and postweighed by the laboratory.

> **Note**: When sampling for silica, either TOTAL and/or RESPIRABLE may be collected, as there are standards for both. In addition, a bulk sample must always be submitted to the laboratory.

Calibration Procedures

- Perform the calibration at the pressure and temperature where the sampling is to be conducted.

- For respirable dust sampling using a cyclone or for total dust sampling using an open-face filter cassette, set up the calibration apparatus as shown in Figure I:1-9.
- Place the open-face filter cassette or cyclone assembly in at least a 1-liter jar. The jar is provided with a special cover.

- Connect the tubing from the electronic positive displacement meter to the inlet of the jar.

- Connect the tubing from the outlet of the cyclone holder assembly or from the filter cassette to the outlet of the jar and then to the sampling pump.

- Calibrate the pump. Readings must be within 5% of each other.

Cyclone Cleaning

- Unscrew the grit pot from the cyclone. Empty the grit pot by turning it upside down and tapping it gently on a solid surface.

- Clean the cyclone thoroughly and gently after each use in warm soapy water or, preferable, wash in an **ultrasonic bath**. Rinse thoroughly in clean water, shake off excess water, and set aside to dry before reassembly. Never insert anything into the cyclone during cleaning. See Figure I:1-2.

- Inspect the cyclone parts for signs of wear or damage such as scoring, rifling, or a loose coupler. Replace the units or parts if they appear damaged.

- Leak test cyclone at least once a month with regular usage.

- Detailed instructions on leak testing are available from the DOSH - CALICO Laboratory.

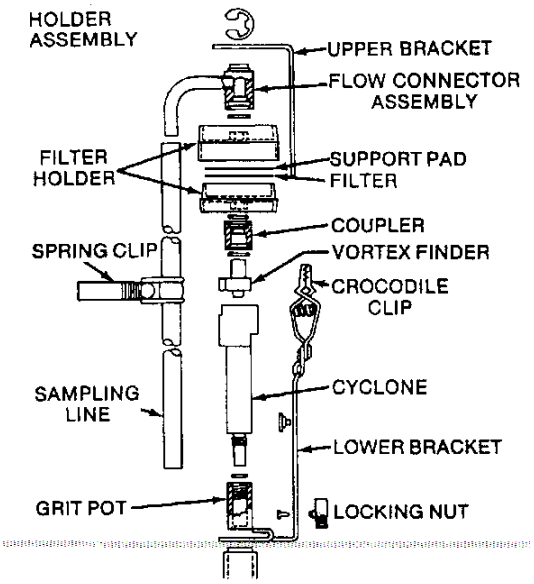

Figure I:1-2. The cyclone (chamber) of the cyclone assembly is sensitive to scratches.

Figure I:1-2a aluminum cyclone

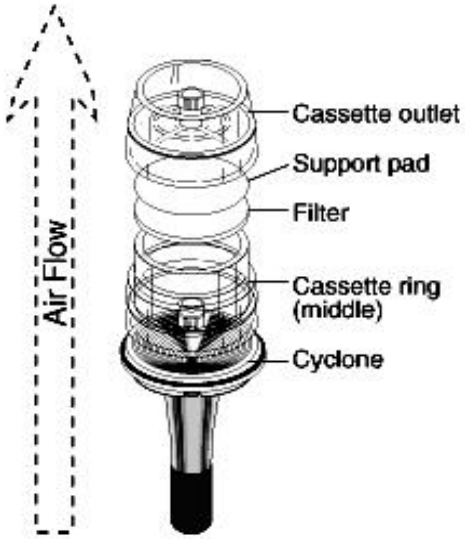

Figure I:1-2b cyclone filter cassette assy.

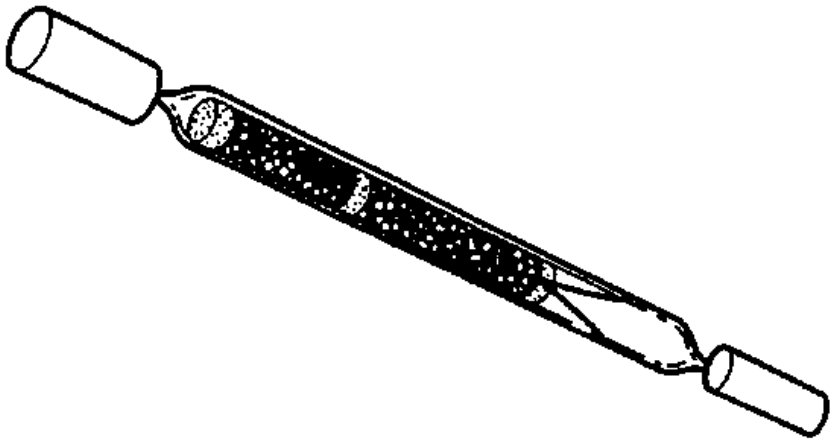

Figure I:1-3. A charcoal or "C"-tube with glass-sealed ends and NIOSH-approved caps before sampling.

SOLID SORBENT TUBES

Organic vapors and gases may be collected on activated charcoal, silica gel, or other adsorption tubes using low-flow pumps.

Immediately before sampling, break off the ends of the flame-sealed tube so as to provide an opening approximately half the internal diameter of the tube. Wear eye protection when breaking ends. Use tube holders, if available, to minimize the hazards of broken glass. Do not use the charging inlet or the exhaust outlet of the pump to break the ends of the tubes.

Use the smaller section of the tube as a back-up and position it near the sampling pump. The tube shall be held or attached in an approximately **vertical** position with the inlet either up or down during sampling.

Draw the air to be sampled directly into the inlet of the tube. This air is not be to passed through any hose or tubing before entering the tube. (A short piece of tubing about ½ long may be placed on the open end to protect the wearer from the jagged end).

Cap the tube with the supplied plastic caps immediately after sampling and seal with a Cal/OSHA 1-HS form as soon as possible. (See Figures I:1-4a and b.) Do not ship with bulk material.

Tubes may be furnished by the laboratory with either caps or flame-sealed glass ends. If using the capped version, simply uncap during the sampling period and recap at the end of the sampling period.

For organic vapors and gases, low-flow pumps are required. Refer to the Chemical Information Manual/OCIS Chemical Sampling Information for flow rates recommended for specific chemicals.

With sorbent tubes, flow rates may have to be lowered or smaller air volumes (half the maximum) used when there is high relative humidity (above 90%) in the sampling area or relatively high concentrations of other organic vapors are present.

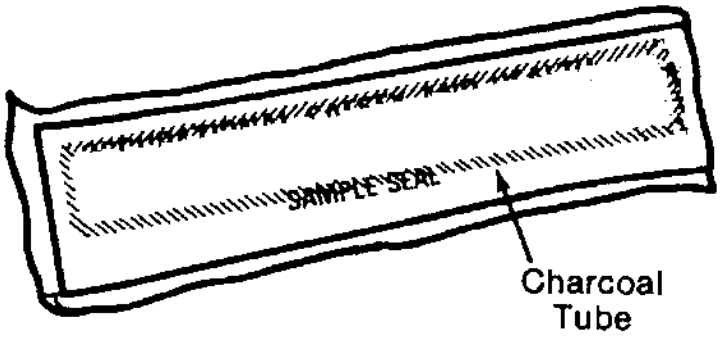

Figure I:1-4a. *Correctly* sealed "C"-Tube. Sample is completely enclosed in the seal, and no tampering is possible.

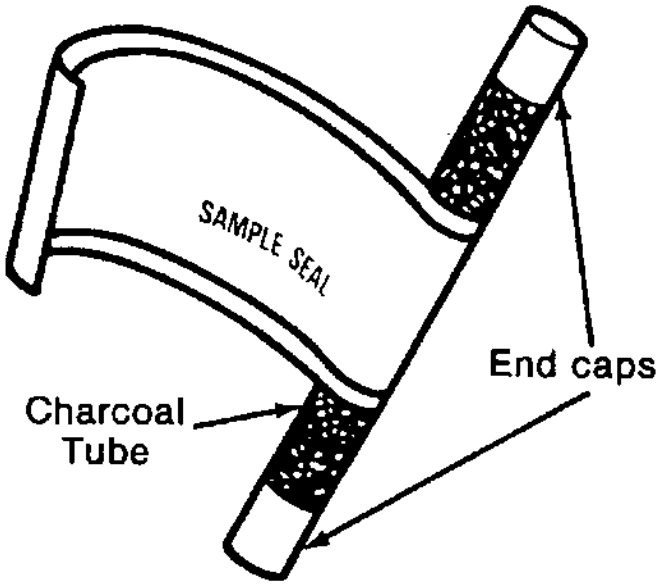

Figure I:1-4b. *Incorrectly* sealed "C"-Tube. End caps can be removed and sample integrity jeopardized without disturbing the seal.

Calibration Procedures

Set up the calibration apparatus as shown in Figure I:1-8 replacing the cassette with the solid sorbent tube to be used in the sampling (e.g. charcoal, silica gel, etc.). If a sampling protocol requires the use of two charcoal tubes, the calibration train must include two charcoal tubes. The air flow must be in the direction of the arrow on the tube.

Calibrate the pump.

MIDGET IMPINGERS AND BUBBLERS

Method

Take care in preparing bubblers and impingers to see that frits or tips are not damaged and that joints can be securely tightened.

Rinse the impinger or bubbler, Figure I:1-5, with the appropriate reagent (see the Chemical Informational Manual/OCIS Chemical Sampling Information and Appendix I:1-4). Then add the specified amount of this reagent to the bubbler or impinger flask either in the office or at the sampling location. If flasks containing the reagent are transported, caps must be placed on the bubbler or impinger stem and side arm.

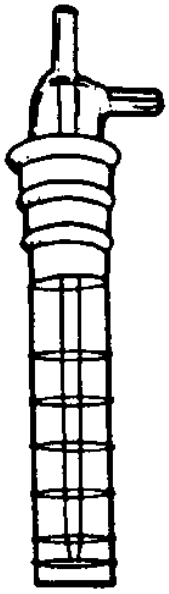

Figure I:1-5. A typical glass impinger

To prevent overflow, do not add over 10 ml of liquid to the midget impingers or bubblers.

Collect contaminants in an impinger or bubbler at a **maximum** flow rate of 1.0 L/min.

The impinger or bubbler may either be hand-held by the industrial hygienist or attached to the employee's clothing using an impinger or bubbler holster. In either case, it is very important that the impinger or bubbler does not tilt and cause the reagent to flow down the side arm to the hose and into the pump.

Note: Attach a trap in line to the pump, if possible. **Non-spill** impingers or bubblers may be necessary for certain applications.

In some instances, it will be necessary to add additional reagent during the sampling period to prevent the amount of reagent from dropping below one half of the original amount.

After sampling, remove the glass stopper and stem from the impinger or bubbler flask.

Rinse the absorbing solution adhering to the outside and inside of the stem directly into the impinger or bubbler flask with a small amount (1-2 ml) of the sampling reagent. Stopper the flask tightly with the plastic cap provided, or pour the contents of the flask into a 20-ml glass bottle. Rinse the flask with a small amount (1-2 ml) of the reagent and pour the rinse solution into the bottle. Tape the cap shut to prevent it from coming loose due to vibration. If electrical tape is used, do not stretch tape since it will contract and loosen the cap.

Calibration

Set up the calibration apparatus as shown in Figure 1:1-8 and replace the cassette with the impinger or bubbler filled with the amount of liquid reagent specified in the sampling method. (Refer to the Chemical Information Manual/OCIS Chemical Sampling Information.)

Connect the tubing from the electronic positive displacement meter to the inlet of the impinger or bubbler.

Connect the outlet of the impinger or bubbler to the tubing to the pump.

Calibrate the pump at a maximum flow rate of 1.0 L/min.

Mailing

Mail bulk samples and air samples separately to avoid cross-contamination. Pack the samples securely to avoid any rattle or shock damage (do not use expanded polystyrene packing). Use bubble sheeting as packing. Put identifying paperwork in every package. Do not send samples in plastic bags or in envelopes. Use Cal/OSHA Forms 1H, 1HS and OSHA Form 91(S), PRINT LEGIBLY ON ALL FORMS. See Section I, Chapter 4. Badges are available from the

laboratory to detect mercury, nitrous oxide, ethylene oxide, formaldehyde, etc. Interfering substances should be noted.

(Figure I:1-6 was deleted.)

D. SPECIAL SAMPLING PROCEDURES

ASBESTOS

Collect asbestos on a special 0.8 micrometer pore size, 25-mm diameter mixed cellulose ester filter with a back-up pad.

Use a fully conductive cassette with conductive extension cowl, Figure I:1-7.

Sample open face in worker's breathing zone.

Ensure that the bottom joint (between the extension and the conical black piece) of the cassette is sealed tightly with a shrink band or electrical tape. Point the open face of the cassette down to minimize contamination.

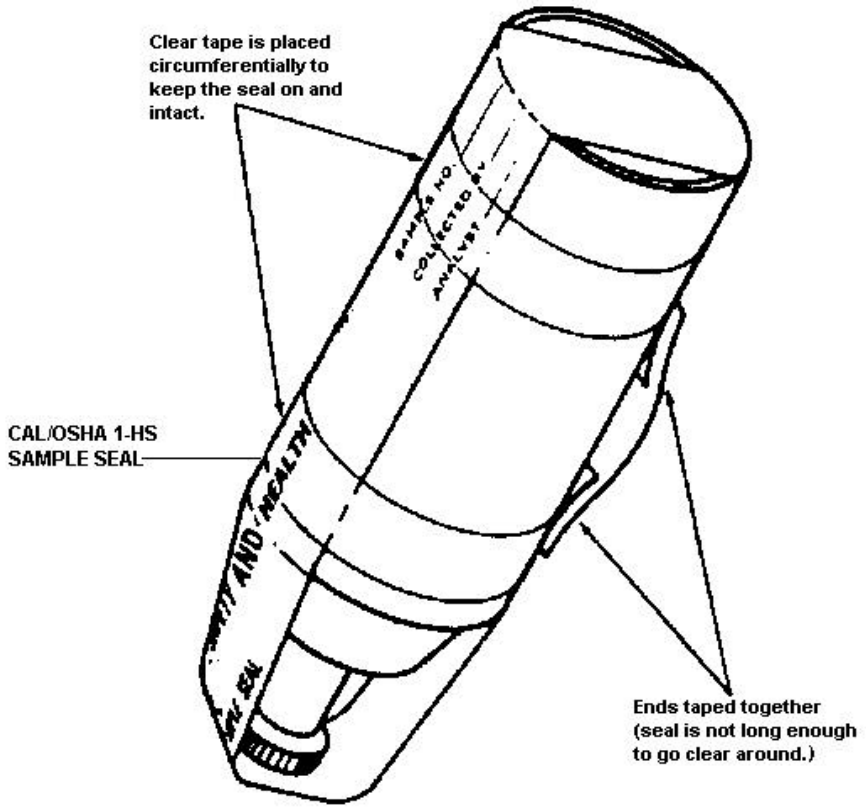

Figure I:1-7. A standard asbestos cassette (25 mm) sealed properly with an CAL/OSHA 1-HS form.

Use a flow rate in the range of 0.5 to 5 L/min. One liter per minute is suggested for general sampling. Office environments allow flow rates of up to 5 L/min. Calibrate pump before and after sampling. Calibration may be done either as in Figure I:1-8 or Figure I:1-9. Do not use nylon or stainless-steel adapters if in-line (Figure I:1-8) calibration is done.

Sample for as long a time as possible without overloading (obscuring) the filter.

Instruct the employee to avoid knocking the cassette and to avoid using a compressed-air source that might dislodge the sample while sampling.

Submit 10% blanks, with a minimum in all cases of two blanks.

Where possible, collect and submit to the Lab, a bulk sample of the material suspected to be in the air.

Mail bulk sample and air samples separately to avoid cross-contamination. Pack the samples securely to avoid any rattle or shock damage (do not use expanded polystyrene packing). Use bubble sheeting as packing. Put identifying paper work in every package. Do not send samples in plastic bags or envelopes. Use OSHA Form 91(S). PRINT LEGIBLY ON ALL FORMS.

This procedure was revised in May 1989. For exceptional sampling conditions or high flow rates, contact the laboratory. More detailed instructions can be obtained from the Laboratory.

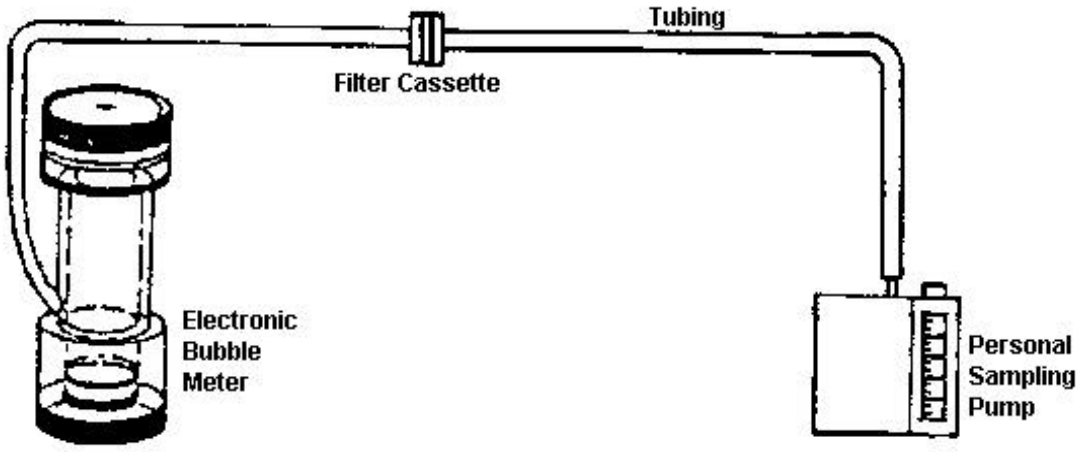

Figure I:1-8. For calibration, the cassette is attached to an electronic bubble meter

SAMPLING FOR WELDING FUMES

When sampling for welding fumes, the filter cassette **must be placed inside** the welding helmet to obtain an accurate measurement of the employee's exposure.

Welding fume samples are normally taken using 37-mm filters and cassettes; however, if these cassette will not fit inside the helmet, 25-mm filters and cassettes can be used. Care must be taken not to overload the 25-mm cassette when sampling.

The Regional Sr. IH or District Manager should be consulted in case of technical difficulties.

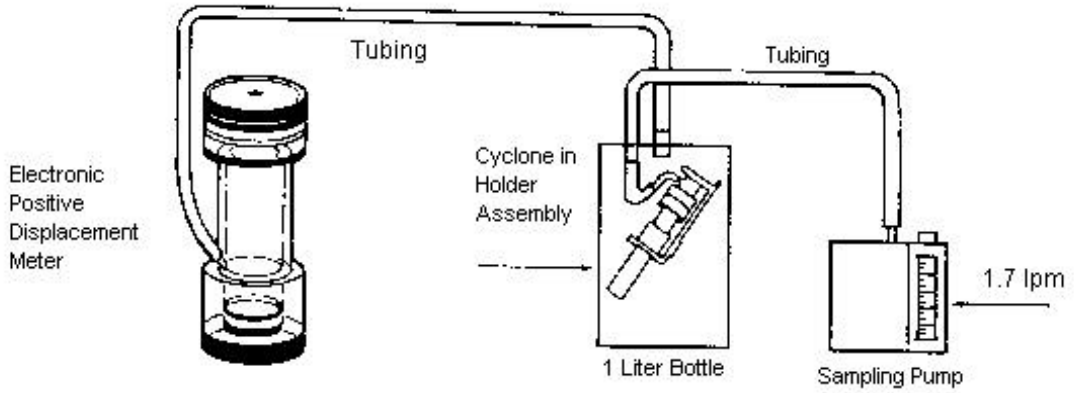

Figure I:1-9. The cyclone is calibrated by placing the cyclone in a 1 liter vessel attached to an electronic bubble meter.

E. EQUIPMENT PREPARATION AND CALIBRATION

ALAKALINE BATTERIES

Replace alkaline batteries monthly. Keep fresh replacement batteries with the equipment.

RECHARGEABLE NI-CAD BATTERIES

Check the rechargeable Ni-Cad batteries in older pumps **under load** (e.g., turn pump on and check voltage at charging jack) before use.

TIME OF CALIBRATION

Calibrate personal sampling pumps before and after each day of sampling, using either the electronic positive displacement meter method or the calibrated precision-rotameter method.

ELECTRONIC FLOW CALIBRATORS

These units are high-accuracy electronic positive displacement flow meters that provide instantaneous air-flow readings and cumulative averaging of multiple samples. These calibrators measure the flow rate of gases and present the results as volume per unit of time.

These calibrators should be used to calibrate all air-sampling pumps. Appendix I:1-2 provides more information on this piece of equipment.

CALIBRATION

When a sampling train requires an unusual combination of sampling media (e.g., glass fiber filter preceding impinger), the same media and devices should be in line during calibration.

Electronic Positive Displacement Meter Method

Allow the pump to run five minutes prior to voltage check and calibration.

Assemble the polystyrene cassette filter holder, using the appropriate filter for the sampling method. Compress cassette by using a mechanical press or other means of applying pressure. Use shrink tape or bands around cassette to cover joints and prevent leakage. If a cassette adapter is used, care should be taken to ensure that it does not come in contact with the back-up pad.

Note: When calibrating with a bubble meter, cassette adapters can cause moderate to severe pressure drop at high flow rates in the sampling train and affect the calibration result. If adapters are used for sampling, they should also be used when calibrating.

CAUTION: Nylon adapters can restrict air flow due to plugging. Stainless-steel adapters are preferred.

Connect the collection device, tubing, pump, and calibration apparatus as shown in Figure I:1-8 for the cassette sampler and figure I:1-9 for the cyclone sampler.

Visually inspect all Tygon tubing connections.

If using an electronic "bubble" meter, wet the inside of the electronic flow cell with the soap solution supplied by pushing on the button several times.

Turn on the pump and adjust the pump rotameter, if available, to the appropriate flow rate.
Press the button on the electronic bubble meter. Visually capture a single bubble and electronically time the bubble.

The accompanying printer will automatically record the calibration reading in liters per minute.

Repeat the step until two readings are within 5%.

If necessary, adjust the pump while it is still running.

Repeat the procedure described above for all pumps to be used for sampling. The same cassette and filter may be used for calibrations involving the same sampling method.

Precision Rotameter Method

The precision rotameter, Figure I:1-10, is a secondary calibration device. If it is to be used in place of a primary device such as a bubble meter, take care to ensure that any error introduced will be minimal and noted.

When using the dry piston positive displacement electronic flow meter, the procedure is the same as with the electronic bubble meter except for the wetting of the cell and generation of a bubble.

Figure I:1-10. A single column precision rotameter can be used as a secondary calibration device.

Replacing the Positive Displacement Meter

The precision rotameter may be used for calibrating the personal sampling pump in lieu of a positive displacement meter, provided it is:

- calibrated regularly, at least monthly, with an electronic positive displacement meter or a bubble meter, as described in Appendix I:1-3;
- disassembled, cleaned as necessary, and recalibrated; (It should be used with care to avoid dirt and dust contamination, which may affect the flow.)
- not used at substantially different temperature and/or pressure from conditions present when the rotameter was calibrated against the primary source; and
- used in such a way that the pressure drop across it is minimized.

Unusual Conditions

If altitude or temperature at the sampling site are substantially different from those at the calibration site, it is necessary to calibrate the precision rotameter at the sampling site.

Manual Buret Bubble Meter Method
See Appendix I:1-3.

F. BIBLIOGRAPHY

American Industrial Hygiene Association (AIHA). 1987. *Fundamentals of Analytical Procedures in Industrial Hygiene*. AIHA: Akron, OH.

Hesketh, H. E. 1986. *Fine Particles in Gaseous Media*. Lewis Publisher, Inc.: Chelsea, MA.

Lioy, P.J. 1989. *Air Sampling Instruments for Evaluation of atmospheric Contaminants*. American Conference of governmental Industrial Hygienists: Cincinnati.

Lodge, J.P. Jr., Ed. 1988. *Method of Air Sampling and Analysis*. Lewis Publishers, Inc.: Chelsea, MA.

National Institute for Occupational Safety and Health (NIOSH). 1977. *Occupational Exposure Sampling Strategy Manual*. DHEW (NIOSH) Publication No. 77-173. U. S. Government Printing Office, Washington, D.C.

Occupational Safety and Health Administration, U.S. Dept. of Labor. 1995. OSHA Computerized Information System (OCIS) Chemical Sampling Information. U. S. Government Printing Office: Washington, D.C.

Division of Occupational Safety and Health, State of California, Department of Industrial Relations. 1982. Industrial Hygiene Technical Manual, Chapter VI, Wipe Samples and Bulk Material Samples.

APPENDIX I:1-1. DETECTOR TUBES AND PUMPS

PRINCIPLE AND DESCRIPTION

Detector tube pumps are portable equipment which, when used with a variety of commercially available detector tubes, are capable of measuring the concentrations of a wide variety of compounds in industrial atmospheres.

Operation consists of using the pump to draw a known volume of air through a detector tube designed to measure the concentration of the substance of interest. The concentration is determined by a colorimetric change of an indicator which is present in the tube contents.

Most detector tubes can be obtained locally.

APPLICATIONS AND LIMITATIONS

Detector tubes and pumps are screening instruments which may be used to measure more than 200 organic and inorganic gases and vapors or for leak detection. Some aerosols can also be measured.

Detector tubes of a given brand are to be used only with a pump of the same brand. The tubes are calibrated specifically for the same brand of pump and may give erroneous results if used with a pump of another brand.

A limitation of many detector tubes is the lack of specificity. Many indicators are not highly selective and can cross-react with other compounds. Manufacturer's manuals describe the effects of interfering contaminants.

Another important consideration is sampling time. Detector tubes give only an instantaneous interpretation of environmental hazards. This may be beneficial in potentially dangerous situations or when ceiling exposure determinations are sufficient. When long-term assessment of occupational environments is necessary, short-term detector-tube measurements may not reflect time-weighted average levels of the hazardous substances present.

Detector tubes normally have a shelf life at 25°C of one to two years. Refrigeration during storage lengthens the shelf life. Outdated detector tubes (i.e., beyond the printed expiration date) should never be used. Training facilities can sometimes use outdated tubes for training purposes.

PERFORMANCE DATA

Specific manufacturers' models of detector tubes are listed in the Chemical Inforamtion Manual/OCIS Chemical Sampling Information. The specific tubes listed are designed to cover a

concentration range that is near the PEL. Concentration ranges are tube-dependent and can be anywhere from one-hundredth to several thousand ppm. The limits of detection depend on the particular detector tube.

Accuracy ranges vary with each detector tube.

The pump may be hand-held during operation (weight 8-11 ounces), or it may be an automatic type (weight about 4 pounds) that collects a sample using a preset number of pump strokes. A full pump stroke for either type of short-term pump has a volume of about 100 ml.

In most cases where only one pump stroke is required, sampling time is about one minute. Determination for which more pump strokes are required take proportionately longer.

Maintenance: Contact the CALICO Lab for long-term maintenance.

Leakage Test

Each day prior to use, perform a pump leakage test by inserting an unopened detector tube into the pump and attempt to draw in 100 ml of air. After a few minutes, check for pump leakage by examining pump compression for bellows-type pumps or return to resting position for piston-type pumps. Automatic pumps should be tested according to the manufacturer's instructions.

In the event of leakage which cannot be repaired in the field, send the pump to the CALICO Lab for repair.

Record that the leakage test was made on the Direct-Reading Data Form (OSHA-93).

CALIBRATION TEST

Calibrate the detector tube pump for proper volume measurement at least quarterly.

Simply connect the pump directly to the bubble meter with a detector tube in-line. Use a detector tube and pump from the same manufacturer.

Wet the inside of the 100 ml bubble meter with soap solution.

For volume calibration, experiment to get the soap bubble even with the zero (0) ml mark of the buret.

For piston-type pumps, pull the pump handle all the way out(full pump stroke) and note where the soap bubble stops; for bellows-type pumps, compress the bellows fully; for automatic pumps, program the pump to take a full pump stroke. For either type pump, the bubble should stop between the 95 ml and 105 ml marks. Allow 4 minutes for the pump to draw the full amount of

air (This time interval varies with the type of detector tube being used in-line with the calibration setup).

Also check the volume for 50 ml (one-half pump stroke) and 25 ml (one-quarter pump stroke) if pertinent. As in Section 1 above, ± 5% error is permissible. If error is greater than ±5%, send the pump to the CALICO Lab for repair and recalibration.

Record the calibration information required on the Calibration Log (OSHA-93).

It may be necessary to clean or replace the rubber bung or tube holder if a large number of tubes have been taken with any pump.

ADDITIONAL INFORMATION

Draeger, Model 31 (Bellows)

When checking the pump for leaks with an unopened tube, the bellows should not be completely expanded after 10 minutes.

Draeger, Quantimeter 1000, Model 1 (Automatic)

A battery pack is an integral part of this pump. The pack must be charged prior to initial use. One charge is good for 1,000 pump strokes. During heavy use, it should be recharged daily. If a "U" (undervoltage) message is continuously displayed in the readout window of this pump, the battery pack should be immediately recharged.

Matheson-Kitagawa, Model 8014-400a (Piston)

When checking the pump for leaks with an unopened tube, the pump handle should be pulled back to the 100 ml mark and locked. After 2 minutes, the handle should be released carefully. It should return to a point<6mm from zero or resting position. After taking 100-200 samples, the pump should be cleaned and relubricated. This involves removing the piston from the cylinder, removing the inlet and pressure-relief valve from the front end of the pump, cleaning, and relubricating.

Mine Safety Appliances, Samplair Pump, Model A, Part No. 46399 (Piston)

The pump contains a flow-rate control orifice protected by a plastic filter which periodically needs to be cleaned or replaced. To check the flow rate, the pump is connected to a buret and the piston is withdrawn to the 100 ml position with no tube in the tube holder. After 24-26 seconds, 80 ml of air should be admitted to the pump. Every 6 months the piston should be relubricated with the oil provided.

MINE SAFETY APPLIANCES

Kwik-Draw Sampling Pump, Part No. 487500 (Bellows)

The pump contains a filter disk that needs periodic cleaning or replacement. The bellows shaft can be cleaned and lubricated with automotive wax if operation becomes jerky.

Sensidyne-Gastec, Model 800, Part No. 7010657-1 (Piston)

This pump can be checked for leaks as mentioned for the Kitagawa pump; however, the handle should be released after 1 minute. Periodic relubrication of the pump head, the piston gasket, and the piston check valve is needed and is use-dependent.

SPECIAL CONSIDERATIONS

Detector tubes should be refrigerated when not in use to prolong shelf life.

Detector tubes should not be used when cold. They should be kept at room temperature or in a shirt pocket for one hour prior to use.

Lubrication of the piston pump may be required if volume error is greater than 5%.

APPENDIX I:1-2. ELECTRONIC FLOW CALIBRATORS

DESCRIPTION

These units are high-accuracy electronic bubble or piston flowmeters that provide instantaneous airflow readings and a cumulative averaging of multiple samples. These calibrators measure the flow rate of gases and report volume per unit of time.

The timer is capable of detecting a soap film or piston at 80-microsecond intervals. This speed allows under steady flow conditions an accuracy of ±0.5% of any display reading. Repeatability is ±0.5% of any display.

The range with different cells is from 1 ml/min to 30L/min.

Battery power will last 8 hours with continuous use. Charge for 16 hours. Can be operated from A/C charger.

MAINTENANCE OF CALIBRATOR

Cleaning Before Use

Remove the flow cell and gently flush with tap water. The acrylic flow cell can be easily scratched. Wipe with cloth only. Do not allow center tube, where sensors detect soap film to be scratched or get dirty. **NEVER clean with ACETONE**. Use only soap and warm water. When cleaning prior to storage, allow flow cell to air dry. If stubborn residue persists, it is possible to remove the bottom plate. Squirt a few drops of soap into the slot between base and flow cell to ease removal.

Dry piston cells should not need cleaning - if so follow the manufacturers instructions.

Leak Testing

The system should be leak checked at 6" H_2O by connecting a manometer to the outlet fitting and evacuate the inlet to 6" H_2O. No leakage should be observed.

Verification Of Calibration

The calibrator is factory calibrated using a standard traceable to National Institute of Standards and Technology (NIST), formerly called the National Bureau of Standards, (NBS). Attempts to verify calibrator against a glass one liter burette should be conducted at 1,000 ml/min. for maximum accuracy. The calibrator is linear throughout the entire range.

SHIPPING AND HANDLING

When transporting, especially by air, it is important that one side of the seal tube which connects the inlet and outlet fitting, be removed for equalizing internal pressure within the calibrator.

Do not transport a bubble unit with soap solution or storage tubing in place.

PRECAUTIONS AND WARNINGS

Avoid the use of chemical solvents on flow cell, calibrator case and faceplate. Generally, soap and water will remove any dirt.

Never pressurize the flow cell at any time with more than 25 inches of water pressure.

Do not charge batteries for longer than 16 hours.

Do not leave A/C adapter plugged into calibrator when not in use as this could damage the battery supply.

Black close fitting covers help to reduce evaporation of soap in a bubble type flow cell when not is use.

Do not store a bubble type flow cell for a period of one week or longer with soap. Clean and store dry.

The soap used in a bubble type calibrator is a precisely concentrated and sterilized solution formulated to provide a clean, frictionless soap film bubble over the wide, dynamic range of the calibrator. The sterile nature of the soap is important in the prevention of residue build-up in the flow cell center tube, which could cause inaccurate readings. The use of any other soap is not recommended.

APPENDIX I:1-3. MANUAL BURET BUBBLE METER TECHNIQUE

When a sampling train requires an unusual combination of sampling media (e.g., glass fiber filter preceding impinger), the same media/devices should be in line during calibration. Calibrate personal sampling pumps before and after each day of sampling.

BUBBLE METER METHOD

1. Allow the pump to run 5 minutes prior to voltage check and calibration.

2. Assemble the polystyrene cassette filter holder using the appropriate filter for the sampling method. If a cassette adapter is used, care should be taken to ensure that it does not come in contact with the back-up pad.

   Note: When calibrating with a bubble meter, the use of cassette adapters can cause moderate to severe pressure drop in the sampling train, which will affect the calibration result. If adapters are used for sampling, then they should be used when calibrating.

3. Connect the collection device, tubing, pump and calibration apparatus as shown in Figures I:1-12 and I:1-13.

4. A visual inspection should be made of all Tygon tubing connections.

5. Wet the inside of a 1-liter buret with a soap solution.

6. Turn on the pump and adjust the pump rotameter to the appropriate flow rate setting.

7. Momentarily submerge the opening of the buret in order to capture a film of soap.

8. Draw two or three bubbles up the buret in order to ensure that the bubbles will complete their run.

9. Visually capture a single bubble and time the bubble from 0 to 1,000 ml for high flow pumps or 0 to 100 ml for low flowpumps.

10. The timing accuracy must be within +1 second of the time corresponding to the desired flow rate.

If the time is not within the range of accuracy, adjust the flow rate and repeat steps 9 and 10 until the correct flow rate is achieved. Perform steps 9 and 10 at least twice, in any event.

While the pump is still running, mark the pump or record on the OSHA-91(S) the position of the center of the float in the pump rotameter as a reference.

Repeat the procedures described above for all pumps to be used for sampling. The same cassette and filter may be used for all calibrations involving the same sampling method.

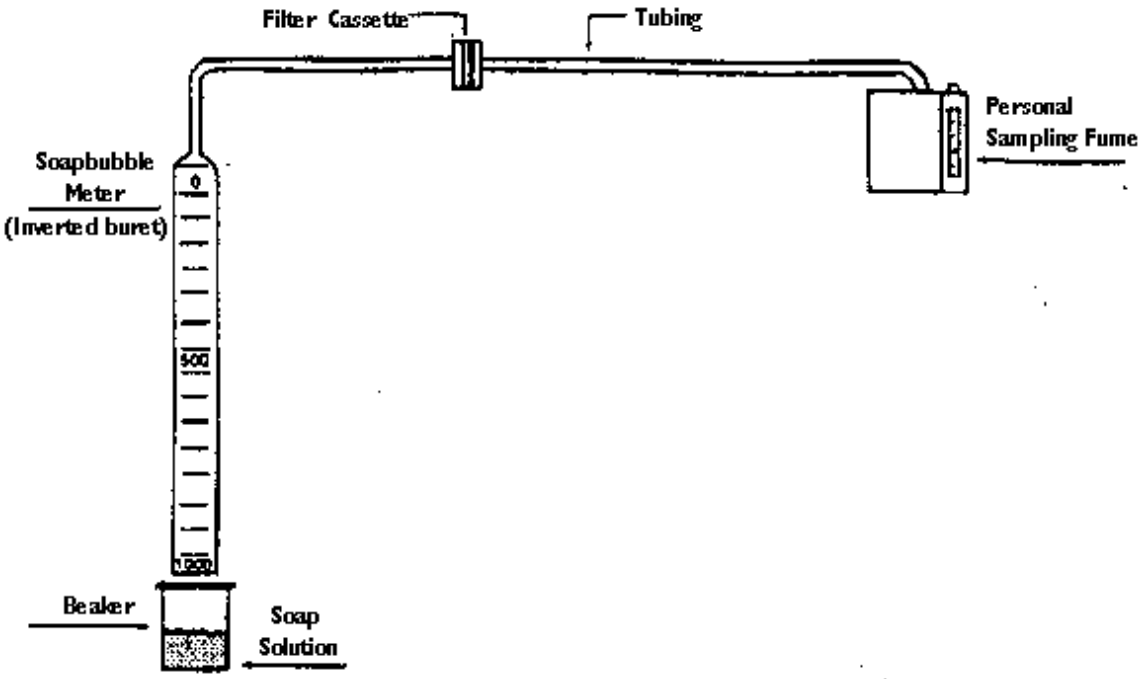

Figure I:1-12. Calibration setup for personal sampling with filter cassette.

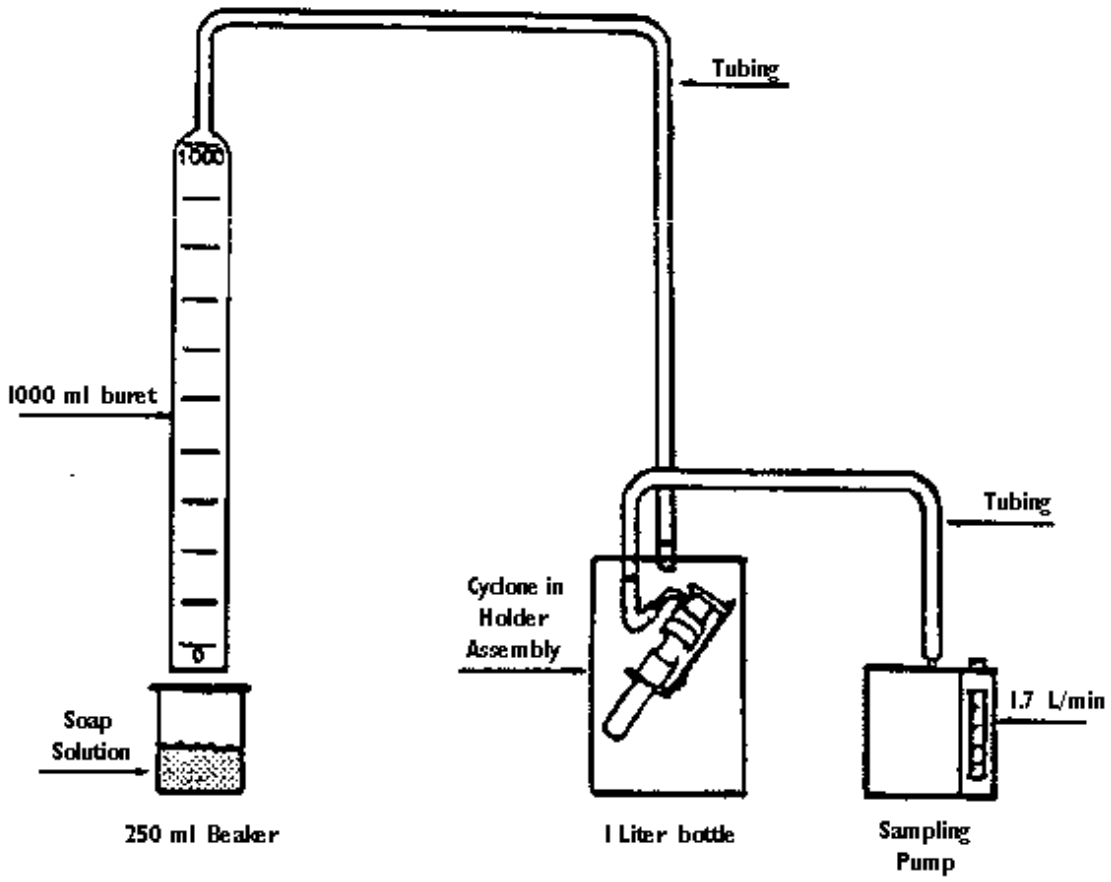

Figure I:1-13. Calibration of cyclone respirable dust sampler using a bubble meter.

APPENDIX I:1-4. SHELF LIFE OF SAMPLING MEDIA

Sampling medium	Shelf life	Comments
Sodium hydroxide (all normalities)	6 months	
Hydrochloric acid Sulfuric acid Methanol in water	1 year	Same for all concentrations of all solutions.
Solution for bis-chloromethyl ether (BCME) and chloromethyl methyl Ether (CMME)	2 months	Must be stored in a dark bottle in a refrigerator.
Hydroxylammonium Chloride solutions (for ketene collection)	2 weeks	Should be stored in a refrigerator in a light-protected container.
Hydroxylammonium chloride-sodium hydroxide mixed solutions (for ketene Collection)	Stable only 2 hours	Must be prepared fresh just prior to use.
Folin's reagent (for Phenols)	5 days	Must be stored in a refrigerator.
Passive monitors	Must be used before the expiration date (if given) printed on the monitor package	
Nitrogen oxides collection tubes		Should be stored in a refrigerator.

APPENDIX I: 1-5. SAMPLING FOR SPECIAL ANALYSES

CRYSTALINE SILICA SAMPLES ANALYZED BY X-RAY DIFFRACTION (XRD)

Air Samples

Respirable dust samples for quartz, cristobalite, and tridymite are analyzed by X-ray diffraction (XRD). XRD is the preferred analytical method due to its sensitivity, minimum requirements for sample preparation and ability to identify polymorphs (different crystalline forms) of free silica.

The analysis of crystalline free silica by XRD requires that the particle size distribution of the samples be matched as closely as possible to the standards. This is best accomplished by collecting a respirable sample.

- Respirable dust samples are collected on a tared low ash PVC filter using a 10-mm nylon cyclone at a flow rate of 1.7 L/min ±0.2 L/min.

- A sample not collected in this manner is considered a total dust (or nonrespirable) sample. CSHOs are discouraged from submitting total dust samples since an accurate analysis cannot be provided by XRD for such samples.

- If the sample collected is nonrespirable, the laboratory must be advised on the OSHA-91(S) form.

Samples are analyzed for cristobalite or tridymite only upon request.

Quartz (also cristobalite and tridymite) is initially identified by its major (primary) X-ray diffraction peak. A few substances also have peaks near the same location, and it is necessary to confirm quartz (also cristobalite or tridymite) using secondary and/or tertiary peaks. To assist the analyst in identifying interference, the IH should provide information concerning potential presence of other substances in the workplace. The following substances should be noted:

- Aluminum phosphate
- Feldspars (microcline, orthoclase, plagioclase)
- Graphite
- Iron carbide
- Lead sulfate
- Micas (biotite, muscovite)
- Montmorillonite
- Potash
- Sillimanite
- Silver chloride
- Talc

- Zircon (Zirconium silicate).

A sample weight and total air volume shall accompany all filter samples. Sample weights of 0.5 to 3.0 mg are preferred.

- Do not submit a sample(s) unless its weight or the combined weights of all particulate filters representing an individual exposure exceed 0.04 mg.

- If heavy sample loading is noted during the sampling period, it is recommended that the filter cassette be changed to avoid collecting a sample with a weight greater than 5.0 milligrams.

Laboratory results for air samples are usually reported under one of four categories:

- **Percent Quartz (or Cristobalite).** Applicable for a respirable sample in which the amount of quartz (or cristobalite) in the sample was confirmed.

- **Less Than or Equal to Value in Units of Percent.** Less than or equal to values are used when the adjusted 8-hour exposure is found to be less than the PEL, based on the sample's primary diffraction peak. The value reported represents the maximum amount of quartz (or cristobalite) that could be present. However, the presence of quartz (or cristobalite) was not confirmed using secondary and/or tertiary peaks in the sample since the sample could not be in violation of the PEL.

- **Approximate Values in Units of Percent.** The particle size distribution in a total dust sample is unknown and error in the XRD analysis may be greater than for respirable samples. Therefore, for total dust samples, an approximate result is given.

- **Nondetected.** A sample reported as nondetected indicates that the quantity of quartz (or cristobalite) present in the sample is not greater than the detection limit of the instrument. The detection limit is usually 10 μg for quartz and 30 μg for cristobalite.

    - If less than a full-shift sample was collected, the IH should evaluate a nondetected result to determine whether adequate sampling was performed.

    - If the presence of quartz (or cristobalite) is suspected in this case, the Industrial Hygienist may want to sample for a longer period of time to increase the sample weights.

Bulk Samples

Bulk samples should be submitted for all silica analyses, if possible.

They have the following purposes:

- To confirm the presence of quartz or cristoblite in respirable samples, or to assess the presence of other substances that may interfere in the analysis of respirable samples.

- To determine the approximate percentage of quartz (or cristobalite) in the bulk sample.

- To support Hazard Communication inspections.

A bulk sample must be representative of the airborne free silica content of the work environment sampled; otherwise, it will be of no value.

The laboratory's order of preference for bulk samples for an evaluation of personal exposure is:

- A high-volume respirable area sample.

- A high-volume area sample.

- A representative settled-dust (rafter) sample. (This is the most practical option. In certain operations it may be very difficult to collect enough material using high-volume sampling to be used as a bulk sample.)

- A bulk sample of the raw material used in the manufacturing process (most practical if used for Hazard Communication inspections).

The type of bulk sample submitted to the laboratory should be stated on the OSHA-91(S) form and cross-referenced to the appropriate air samples.

A reported bulk sample analysis for quartz (also cristobalite or tridymite) will be semiquantitative because:

- error associated with bulk sampling;
- the XRD analysis procedure requires a thin layer deposition for an accurate analysis; and
- the error for bulk samples analyzed by XRD is unknown because the particle size of nonrespirable bulk samples varies from sample to sample.

SAMPLES ANALYZED BY INDUCTIVELY COUPLED PLASMA (ICP) METALS

Metals

Where two or more of the following analytes are requested on the same filter, an ICP analysis may be conducted. However, the Industrial Hygienist should specify the metals of interest in the event samples can not be analyzed by the ICP method. A computer printout of the following 12 analytes may be reported:

- Antimony
- Beryllium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Manganese
- Molybdenum
- Nickel
- Vanadium
- Zinc.

Samples taken during abrasive blasting operations are no longer analyzed by ICP because of difficulties with heavy loadings. These samples can be analyzed by atomic absorption spectrometry (AAS) for specific metals (i.e, Pb, Cd, Cr, Fe).

Cadmium

Samples analyzed for the analytes mentioned above can also be analyzed for cadmium on request.

SAMPLES ANALYZED BY X-RAY FLUORESCENCE (XRF)

Filter, wipe, and bulk samples can be qualitatively analyzed by XRF.

Requests for XRF analyses should be preceded by a phone call to the laboratory to determine the extent and value of the analysis.

Packaging and shipping of such samples should be done in a manner consistent with directions previously given in this chapter.

APPENDIX I:1-6. SAMPLING AND ANALYTICAL ERRORS (SAEs)

DEFINITION OF SAEs

When an employee is sampled and the results analyzed, the measured exposure will rarely be the same as the true exposure. This variation is due to sampling and analytical errors, or SAEs. The total error depends on the combined effects of the contributing errors inherent in sampling, analysis, and pump flow.

Definition Of Confidence Limits

Error factors determined by statistical methods shall be incorporated into the sample results to obtain the lowest value that the true exposure could be (with a given degree of confidence) and also the highest value the true exposure could be (also with some degree of confidence).

The lower value is called the lower confidence limit (LCL), and the upper value is the upper confidence limit (UCL). These confidence limits are termed one-sided since the only concern is with being confident that the true exposure is on one side of the PEL.

DETERMINING SAEs

SAEs that provide a 95% confidence limit have been developed and are listed on each Analytical Laboratory report form (most current SAEs). If there is no SAE listed in the report for a specific substance, call the Analytical Laboratory. If using detector tubes or direct-reading instruments, use the SAEs provided by the manufacturer.

ENVIRONMENTAL VARIABLES

Environmental variables generally far exceed sampling and analytical errors. Samples taken on a given day are used by Cal/OSHA(the Division) to determine compliance with PELs. However, where samples are taken over a period of time (as is the practice of some employers), the IH should review the long-term pattern and compare it with the results. When the Division's samples fit the long-term pattern, it helps to support the compliance determination. When the Division's results differ substantially from the historical pattern, the IH should investigate the cause of this difference and perhaps conduct additional sampling.

CONFIDENCE LIMITS

One-sided confidence limits can be used to classify the measured exposure into one of three categories.

- If the measured results do not exceed the standard and the UCL also does not exceed the standard, we can be 95% confident that the employer is in compliance. (See Equation I:1-6E.)

- If the measured exposure exceeds the PEL and the LCL of that exposure also exceeds the PEL, we can be 95% confident that the employer is in noncompliance, and a violation is established. (See Equation I:1-6F.)

- If the measured exposure does not exceed the PEL, but the UCL of that exposure does exceed the PEL, we cannot be 95% confident that the employer is in compliance. (See Equation I:1-6E.) Likewise, if the measured exposure exceeds the PEL, but the LCL of that exposure is below the PEL, we cannot be 95% confident that the employer is in compliance. (See Equation I:1-6F.) In both of these cases, the measured exposure can be termed a "possible overexposure."

    - A violation is not established if the measured exposure is in the "possible overexposure" region. It should be noted that the closer the LCL comes to exceeding the PEL, the more probable it becomes that the employer is in noncompliance.

    - If measured results are in this region, the IH should consider further sampling, taking into consideration the seriousness of the hazard, pending citations, and how close the LCL is to exceeding the PEL.

    - If further sampling is not conducted, or if additional measured exposures still fall into the "possible overexposure" region, the IH should carefully explain to the employer and employee representative in the closing conference that the exposed employee(s) may be overexposed but that there was insufficient data to document noncompliance. The employer should be encouraged to voluntarily reduce the exposure and/or to conduct further sampling to assure that exposures are not in excess of the standard.

SAMPLING METHODS

The LCL and UCL are calculated differently depending upon the type of sampling method used. Sampling methods can be classified into one of three categories:

- **Full-period, Continuous Single Sampling.** Full-period, continuous single sampling is defined as sampling over the entire sample period with only one sample. The sampling may be for a full-shift sample or for a short period ceiling determination.

- **Full-period, Consecutive Sampling.** Full-period, consecutive sampling is defined as sampling using multiple consecutive samples of equal or unequal time duration which, if

combined, equal the total duration of the sample period. An example would be taking four 2-hour charcoal tube samples. There are several advantages to this type of sampling.

- If a single sample is lost during the sampling period due to pump failure, gross contamination, etc., at least some data will have been collected to evaluate the exposure.

- The use of multiple samples will result in slightly lower sampling and analytical errors.

- Collection of several samples allows conclusions to be reached concerning the manner in which differing segments of the work day affect overall exposure.

- **Grab Sampling.** Grab sampling is defined as collecting a number of short-term samples at various times during the sample period which, when combined, provide an estimate of exposure over the total period. Common examples include the use of detector tubes or direct-reading instrumentation (with intermittent readings).

CALCULATIONS

If the initial and final calibration flow rates are different, a volume calculated using the highest flow rate should be reported to the laboratory. If compliance is not established using the lowest flow rate, further sampling should be considered.

Generally, sampling is conducted at approximately the same temperature and pressure as calibration, in which case no correction for temperature and pressure is required and the sample volume reported to the laboratory is the volume actually measured. When sampling is conducted at a substantially different temperature or pressure than calibration, an adjustment to the measured air volume may be required depending on sampling pump used, in order to obtain the actual air volume sampled.

The actual volume of air sampled at the sampling site is reported, and used in all calculations.

- For particulates, the laboratory reports mg/m^3 of contaminant using the actual volume of air collected at the sampling site. The value in mg/m^3 can be compared directly to T8CCR 5155.

- The laboratory normally does not measure concentrations of gases and vapors directly in parts per million (ppm). Rather, most analytical techniques determine the total weight of contaminant in collection medium. Using the air volume provided by the IH, the lab calculates concentration in mg/m^3 and converts this to ppm at 25°C and 760 mm Hg using Equation I:1-6A. This result is to be compared with the PEL without adjustment for temperature and pressure at the sampling site. $ppm^{NTP}=mg/m^3(24.45)/(Mwt)$.

Mwt = molecular weight

NTP = Normal Temperature and Pressure, 25°C and 760 mm Hg.

Equation I:1-6A

ppm(NTP) = mg/m^3(24.45)/(Mwt)

Where:

24.45 = molar volume at 25°C (298°K) and 760 mm Hg

Mwt = molecular weight

NTP = Normal Temperature and Pressure at 25°C and 760 mm Hg

- If it is necessary to know the actual concentration in ppm at the sampling site, it can be derived from the laboratory results reported in ppm at NTP by using the following equation:

Equation I:1-6B

ppm(PT) = ppm(NTP)(760)/(P)(T)/(298)

where:

P = sampling site pressure (mm of Hg)

T = sampling site temperature (°K)

298 = temperature in degrees Kelvin (273°K + 25°)

Equation I:1-6C

since ppm(NTP) = mg/m^3 (24.45)/(Mwt)
ppm(PT) = mg/m^3 X 24.45/Mwt X 760/P X T/298

Note: When a laboratory result is reported as mg/m^3 contaminant, concentrations expressed as ppm (PT) cannot be compared directly to the standards table without converting to NTP.

Note: Barometric pressure can be obtained by calling the local weather station or airport, request the unadjusted barometric pressure. If these sources are not available then a rule of thumb is: for every 1,000 feet of elevation, the barometric pressure decreases by 1 inch of Hg.

CALCULATION METHOD FOR A FULL-PERIOD, CONTINUOUS SINGLE SAMPLE

Obtain the full-period sampling result (value X), the PEL and the SAE. The SAE can be obtained from the *Chemical Information Manual or Laboratory Report.*

Divide X by the PEL to determine Y, the standardized concentration. That is:

Equation I:1-6D

$$Y = X/PEL$$

Compute the UCL (95%) as follows:

Equation I:1-6E

$$UCL\ (95\%) = Y + SAE$$

Compute the LCL (95%) as follows:

Equation I:1-6F

$$LCL\ (95\%) = Y - SAE$$

Classify the exposure according to the following classification system:

- If the UCL ≤ 1, a violation does not exist.
- If LCL ≤ 1 and the UCL > 1, classify as possible overexposure.
- If LCL > 1, a violation exists.

CALCULATION METHOD FOR FULL-PERIOD CONSECUTIVE SAMPLING

The use of multiple consecutive samples will result in slightly lower sampling and analytical errors than the use of one continuous sample since the inherent errors tend to partially cancel each other. The mathematical calculations, however, are somewhat more complicated. If preferred, the IH may first determine if compliance or noncompliance can be established using the calculation method noted for a full-period, continuous, single-sample measurement. If results fall into the

"possible overexposure" region using this method, a more exact calculation should be performed using equation I:1-6G.

Equation I:1-6G

- Obtain X_1, X_2 …, X_n, the n consecutive concentrations on one workshift and their time durations, T_1, T_2, …, T_n.

  Also obtain the SAE listed in the Laboratory report form

- Compute the TWA exposure.

- Divide the TWA exposure by the PEL to find Y, the standardized average (TWA/PEL).

- Compute the UCL (95%) as follows:

  UCL (95%) = Y + SAE (Equation I:1-6E)

- Compute the LCL (95%) as follows:

  LCL (95%) = Y - SAE (Equation I:1-6F)

Classify the exposure according to the following classification system:

- If UCL ≤ 1, a violation does not exist.

- If LCL<1, and the UCL > 1, classify as possible overexposure.

- If LCL >1, a violation exists.

When the LCL ≤ 1.0 and UCL > 1.0, the results are in the "possible overexposure" region and the IH must analyze the data using the more exact calculation for full-period consecutive sampling, as follows:

Equation I:1-6H

$$LCL = Y - \frac{SAE\sqrt{T_1^2X_1^2 + T_2^2X_2^2 \ldots + T_n^2X_n^2}}{PEL(T_1 + T_2 \ldots + T_n)}$$

GRAB SAMPLING

If a series of grab samples (e.g., detector tubes) are used to determine compliance with either an 8-hour TWA limit or a ceiling limit, consult with the Sr. IH for Technical Support regarding sampling strategy and the necessary statistical treatment of the result obtained.

SAEs FOR EXPOSURE TO CHEMICAL MIXTURES

Often an employee is simultaneously exposed to a variety of chemical substances in the workplace. Synergistic toxic effects on a target organ are common for such exposures in many construction and manufacturing processes. This type of exposure can also occur when impurities are present in single chemical operations. New permissible exposure limits for mixtures, such as the recent welding fume standard (5 mg/m^3), address the complex problem of synergistic exposures and their health effects. In addition, T8CCR 5155 contains a computation approach to access exposure to a mixture. This calculation should be used when components in the mixture pose a synergistic threat to worker health.

Whether using a single standard or the mixture calculation, the sampling and analytical error (SAE) of the individual constituents must be considered before arriving at a final compliance decision. These SAEs can be pooled and weighted to give a control limit for the synergistic mixture. To illustrate this control limit, the following example using the mixture calculation is shown:

The mixture calculation is expressed as:

Equation I:1-6I.

$$E_m = (C_1/L_1 + C_2/L_2) + \ldots C_n/L_n$$

Where:

E_m = equivalent exposure for a mixture (E_m should be ≤ 1 for compliance)
C = concentration of a particular substance
L = PEL

For example, to calculate exposure to three different but synergistic substances:

Material	8-hr. exposure	8-hour TWA PEL (ppm)	SAE
Substance 1	500	1,000	0.089
Substance 2	80	200	0.11
Substance 3	70	200	0.18

Using Equation I:1-6I: $E_m = 500/1{,}000 + 80/200 + 70/200 = 1.25$

Since $E_m > 1$, an overexposure appears to have occurred; however, the SAE for each substance also needs to be considered:

- Exposure ratio (for each substance) $Y_n = C_n/L_n$
- Ratio to total exposure $R_1 = Y_1/E_m$,…$R_n = Y_n/E_m$

The SAEs (95% confidence) of the substance comprising the mixture can be pooled by:

$(RS_1)^2 = (R_1)^2(SAE_1)^2 + (R_2)^2(SAE_2)^2 + \ldots (R_n)^2(SAE_n)^2$

The mixture Control Limit (CL) is equivalent to: $1 + RS_t$

If $E_m \leq CL$, then an overexposure has not been established at the 95% confidence level; further sampling may be necessary.

If $E_m > 1$ and $E_m > CL$, then an overexposure has occurred (95% confidence).

Using the mixture data above:

$Y_1 = 500/1{,}000$	$Y_2 = 80/200$	$Y_3 = 70/200$
$Y_1 = 0.5$	$Y_2 = 0.4$	$Y_3 = 0.35$
$R_1 = Y_1/E_m = 0.4$	$R_2 = 0.32$	$R_3 = 0.28$

$(RS_1)^2 = (0.4)^2(0.089)^2 + (0.32)^2(0.11)^2 + (0.28)^2(0.18)^2$

$RS_t = [(RS_t)^2]^{1/2} = 0.071$

$CL = 1 + RS_t = 1.071$

$E_m = 1.25$

Therefore $E_m > CL$ and an overexposure has occurred within 95% confidence limits. This calculation is also used when considering a standard such as the one for total welding fumes. A computer program is available for personal computers which will calculate a control limit for any synergistic mixture. The program will run on any IBM compatible computer.

SAMPLE CALCULATION FOR FULL-PERIOD, CONTINUOUS SINGLE SAMPLE

A single fiberglass filter and personal pump were used to sample for carbaryl for a 7-hour period. The IH was able to document that the exposure during the remaining unsampled one-half hour of the 8-hour shift would equal the exposure measured during the 7-hour period. The laboratory reported 6.07 mg/m^3. The SAE for this method is 0.23. The PEL is 5.0 mg/m^3.

Step 1. Calculate the standardized concentration.

$Y = 6.07/5.0 = 1.21$

Step 2. Calculate confidence limits.

$LCL = 1.21 - 0.23 = 0.98$
Since the LCL does not exceed 1.0, noncompliance is not established. The UCL is calculated:

$UCL = 1.21 + 0.23 = 1.44$

Step 3. Classify the exposure.

Since the LCL ≤ 1.0 and the UCL > 1.0, classify as possible overexposure.

SAMPLE CALCULATION FOR FULL-PERIOD CONSECUTIVE SAMPLING

If two consecutive samples had been taken for carbaryl instead of one continuous sample, and the following results were obtained:

	--Sample--	
	A	**B**
Sampling rate (L/min)	2.0	2.0
Time (min)	240	210
Volume (L)	480	420
Weight (mg)	3.005	2.457
Concentration (mg/m^3)	6.26	5.85

The SAE for carbaryl is 0.23

Step 1. Calculate the UCL and the LCL from the sampling and analytical results:

TWA = (6.26 mg/m^3) 240 min + (5.85 mg/m^3) 210 min

450 min = 6.07 mg/m^3

$Y = 6.07\ mg/m^3/PEL = 6.07/5.0 = 1.21$

Assuming a continuous sample: LCL = 1.21 - 0.23 = 0.98

UCL = 1.21 + 0.23 = 1.44

Step 2. Since the LCL < 1.0 and UCL > 1.0, the results are in the possible overexposure region, and the CSHO must analyze the data using the more exact calculation for full-period consecutive sampling as follows:

$$LCL = 1.21 - \frac{0.23\sqrt{(240\ \text{min})^2(6.26\text{mg/m}^3)^2 + (210\ \text{min})^2(5.85\ \text{mg/m}^3)^2}}{5.0\ \text{mg/m}^3(240 + 210\ \text{min})}$$

$$= 1.21 - 0.20 = 1.01$$

Since the LCL > 1.0, a violation is established.